Case Study and Apprenticeship Pedagogy for Training Construction Engineering Students

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Abstract*— The guide to professional development via apprenticeship promotes the following initiatives: improved delivery of educational material and alternate methods for evaluation of the learning objectives. The research herein will focus on utilizing the industry professional based apprenticeship with case study instruments in the classroom improving student motivation, the professional development and critical thinking skills of the student. A byproduct of the research will include providing the instructor with scholarly reflection to meet the aforementioned objectives. Objectives considered in this study are answering to the questions such as, how should we prepare construction engineering students for professional practice? How can we link technical skills together with applied (experiential learning) and professional skills (soft skills) to produce the best construction engineering professional possible? Can we train students to develop the skill sets to determine cause-effect with supporting claims and have the imagination to develop solutions with impact in mind? The results offer the baseline insight that was sought relative to the student critical thinking related to the case study pedagogy. The research provides an opportunity for the researcher to self-evaluate the manner in which the instruction is developed and delivered.

***Keywords*— Apprenticeship pedagogy; Construction Engineering; Industry trends; Self-evaluation; Critical thinking; Experiential learning; Internship**

I. INTRODUCTION

The Division of Construction Engineering and Management (CEM) at Purdue University has existed since the late 1970's. The formation of CEM was cultivated by the efforts of the Indiana general contractor population to provide a bridge between the owner/engineer and construction trades. The program has developed into a leader nationally and internationally with its construction, engineering and management based curriculum that includes a required series of experiential industry work experiences prior to graduation. The link with the construction industry is significant and the overall influence is infinite. The construction industry employs millions of Americans and is a multi-billion dollar industry [1]. The landscape of the construction industry is changing as it becomes more competitive, global and thirsts for implementation of measures to enhance the delivered product.

The opportunity exists to link the industry and academia further than that which already exists in the CEM structure to benefit the student, the future industry professional. Industry is application, whereas the current plan of study is theory which limits the students from starting to develop a decision matrix of experience that assists them in making sound engineering decisions in a timely manner. The so called limitations that exist in the academic and professional (experiential) environments – also defined in the forthcoming sections, as well as, the need to train the future industry professional is the driving force for the research described within. Anecdotal references by students support this claim of limitations. The experiential limitations exist as pressures of every day production, schedule and training of mentors fall short of the necessary student enrichment. The academic limitations are associated with space, applicable experiences and the need to meet academic objectives set forth by University Policy and/or by the accreditation body (ABET). CEM at Purdue University is closing in on a curriculum renaissance and the stepping stone is the pedagogical method investigated within this paper.

CEM is training future construction professionals (students) with appropriate knowledge to be leaders in the engineering and construction industry. As part of the training of the future construction professionals, CEM is committed to scholarship of teaching which leads us to the research found within. Content and training of the construction professional needs to stay in front of the ever changing landscape of the industry. It is important to find a way to bridge the student's perceived gap between academics and the experiential learning they encounter during their years at Purdue. The gap between theory and practice in engineering disciplines is real [2]. In the end, the research within is a sub exploration that could lead to overall curriculum change and pedagogical improvements in how the construction engineering discipline is delivered by "making learning whole" [3] which will create more agile and critical thinking individuals. The self-described renaissance started with the introduction of CEM 28000: Construction Engineering Professional Development I course during the Spring of 2015. This course is a new development for CEM and has implemented improved teaching methods to address the way in which currents students learn with an eye on improved student motivation. The pedagogical method, case study delivery of content, has been implemented and research conducted on assignments assigned in CEM 28000. The case study method represents a mini-game as part of "making learning whole" [3]. CEM 28000 is a sophomore level course which has 23 students (3 female and 20 male) enrolled for the Spring 2015 semester – at the time of performing this case study. The course is required as part of the plan of study for

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student's in the Purdue Division of Construction Engineering and Management. The students are young, impressionable and growing intellectually. The students are starting to evaluate principles and develop a few arguments in their problem solving approaches. The development of their intellectual skills is attributed to their on-campus academic endeavors as well as completion of at least one internship by each student prior to taking the class. The goal of the CEM curriculum is to develop critical thinking and judgment skills which supports the student (future professional) in asking questions and logically solving challenging engineering situations.

The innovative practice proposed herein is a blend of the apprenticeship method implemented by the construction trades and utilized by other professional disciplines while utilizing case study material developed by the industry professionals, such as lawyers and management/medical professionals. The apprenticeship for the construction engineering student differs from that of the union trade (in field application) due to the current lack of facilities on campus to craft the necessary scenarios in support of contextual application of the apprenticeship. The construction engineering apprenticeship is analogous to the residency in the medical profession. The guide to professional development via apprenticeship promotes the following initiatives: improved delivery of educational material and alternate methods for evaluation of the learning objectives. The research herein will focus on utilizing the industry professional based apprenticeship with case study instruments in the classroom improving student motivation, the professional development and critical thinking skills of the student. A byproduct of the research will include providing the instructor with scholarly reflection to meet the aforementioned objectives.

II. Literature Review

Construction engineering scholarly work associated with case based instruction is limited; therefore, the research has expanded to include other works that can provide transferable knowledge that can be applied. It is interesting to note that several of the key pieces of literature on case study pedagogy reflect the day to day activities observed by the researcher. This validation is important to make so we can support our assertion of transferability.

The contribution to engineering education is the proposed industry sponsored apprenticeship using case studies as the instrument of delivery. The described instruction appears to differ from previously developed models because a professional will participate in the classroom and the assessment will be more rigorous; whereas, previous descriptions of case studies in engineering instruction have reported only student satisfaction measures [2], we have assessed student learning outcomes. The purpose behind the case study methodology extends beyond the motivation of student learning but the need to expose the student to interdisciplinary learning, the need to utilize different skill sets that are not akin to the specific technical approach found in most engineering programs [2]. It is fair to state that the case study pedagogy is an appropriate manner in which to train our future engineers but very few faculty know how to administer the case study in the classroom [2]. The research will provide us with scholarly approaches to teaching and define practices that will improve the delivery of the content.

Case-based instruction (CBI), learner-centered pedagogies, makes material more relevant and increases motivation for students [4]. The traditional method of instruction, lecture based, does not appeal to today's student and does not provide adequate training as needed for professional development/readiness. The students who come in contact with material delivered via CBI are more likely to grow and grasp the conceptual understanding of a topic than those who sit through a traditional lecture [4]. CBI promotes authentic situations and embedded scenarios that the students learn application in the confines of the institution further bridging the gap between theory and application.

A significant difference with this study regarding the creation of the case study is that the industry professional will craft the narrative, questions and deliver in class. This will give an authentic description and industry feel to the case study rather than the tint that would be associated with a paper crafted by academia. According to the Raju study, the instructor's visited the project and drafted the case study with the collaboration of the parties whom they consulted for the material [2]. In addition, this study moves past and accepts the notion that the students enjoy the case study delivery so that a baseline is determined. We can now focus on the type of learning and quality of the learning.

It is apparent that Yadav has partially embraced the later part of the previous statement and is focused on the influence of students' conceptual understanding [4]. Yadav compares the delivery to the traditional role of the lecture based delivery method. It is understood that it is interesting to compare the two when it comes to deeper cognition but the work by Yadav [4] and Raju [2] provide the researchers with adequate evidence that we must look at the quality of the output, the student, so we can adapt the case study pedagogy and effectively maximize the output. Students are able to better understand conceptually the topics within their discipline; therefore, we must improve the delivery training for the instructor and the format for the student.

There have been significant changes in undergraduate construction engineering and management curricula in the recent decades. Preparing students to have suitable skills and characteristics to succeed in the industry is a challenging topic for university curriculum committees. Objectives considered in this study are answering to the questions such as, how should we prepare construction engineering students for professional practice? How can we link technical skills together with applied (experiential learning) and professional skills (soft skills) to produce the best construction engineering professional possible? Can we train students to develop the skill sets to determine cause-effect with supporting claims and have the imagination to develop solutions with impact in mind? The results offer the baseline insight that was sought relative to the student critical thinking related to the case study pedagogy. The research provides an opportunity for the researcher to self-evaluate the manner in which the instruction is developed and delivered.

III. METHODS

The following process, refer to Table 1, outlines the general application of the case study and apprenticeship pedagogy for the purpose of this research:

1. Case study exercises were randomly offered throughout the Spring 2015 semester CEM 28000, a sophomore based course. The overall assignment is part of the academic standard operating procedure for the course which makes this authentic within the rhythm of the course.

2. In particular for the purpose of this research; a case study was provided to the student at the beginning of the semester 48 hours prior to the primary author attending class and delivering the case study. The students were expected to read the (300-500 word) case narrative authored by a construction engineering professional. The students submitted questions via Blackboard, the course management system, prior to the next class when the primary author would be in attendance. This allowed the author to have student insight on the problem; as well as, this activity promoted student interaction in advance.

3. The primary author took a brief amount of time to introduce the case study at the start of the 50 minute class highlighting the points of emphasis prior to splitting the students into pairs or small groups. The author addressed any of the significant questions the students posted and/or offered them resources to answer their questions on their own.

4. The author asked the students additional questions about the case. The students separated and engaged in a series of think-pair-share activities with their group while the author circulated throughout the classroom supporting and interacting with students in real-time (apprenticeship).

5. Students further engaged with the author and other students as they reported out their collective thoughts on the questions posed regarding the case study through case discussion [4].

6. The final step in the case study pedagogy was for the student to synthesis all of the knowledge that was shared throughout the specific case study. The synthesis is a loose assignment that requires the student to prepare a document to be posted on Blackboard. The document should reflect one that would be utilized professionally to address the challenge, support decisions and informs others of the course of action. Specific to the construction engineering student, the response will focus on: engineering, scheduling, budget, and stakeholder impact that must be addressed either by experience or input by others. Through the case study apprenticeship process, students develop the critical thinking skills that they need as professional construction engineers.

The author provided the documentation in advance of class, discussed in class and the students responded by submitting their responses as described in item 6. The unconstrained approach, lack of rubric, will be discussed further in the "Discussion" section. It should be noted that the freeform permitted mirrors ambiguous engineering challenges in industry [2, 4] but does not support the necessary mentoring the student needs in the undergraduate experience.

TABLE I. LESSON PLAN FOR TYPICAL CASE STUDY

Time	**Student Responsibility**	**Instructor/Author Responsibility**	**Notes**
48 hrs prior to class	Case study reviewed	Instructor posts case study	
0:00-0:05 min		Author to introduce and summarize 1-2 important elements of the case study	
0:05-0:20 min	Groups form and investigate 1-2 questions	Author should work from group to group investigating their approach and challenging them on their assumptions	Groups should be predetermined to save time and disperse experiences
0:20-0:30 min	Report out on questions 1-2	Author to mediate and facilitate discussion	
0:30-0:40 min	Group investigates question(s) 3-4	Author should work from group to group investigating their approach and challenging them on their assumptions	More questions can be introduced beyond 4. Groups should be assigned only one question during this segment
0:40-0:50 min	Report out on question 3 – 4 (each group assigned a separate question)	Author to mediate and facilitate concise discussion	
48 hrs after the class	Synthesis and Submission	Feedback and Evaluation	

The collection of the assignment for research purposes is not only appropriate because of the nature of the research topic but the method in which the analysis is being conduct is appropriate. The case study response (assignment) is authentic and part of the normal operating procedures within the course. The students should provide an accurate and thorough response since the assignment is anchored in their field of study. Had the research been conducted on an element outside the student expertise, then we would find them providing less cognitive effort in their responses – the data should be rich as a result. Final thought on appropriateness relates to the scholarship of teaching. The research provides an opportunity for the researcher to self-evaluate the manner in which the instruction is developed and delivered.

The assignments produced by the students were collected from Blackboard, graded and then de-identified. The de-identified artifacts and assignments were reviewed with respect to their approach to solving the problem, imagination, depth of understanding and presentation. The goal of the analysis is to develop a baseline understanding of the critical thinking of the student – an insight that will trigger further investigative research. The baseline will be created using the following criteria to evaluate and group the assignments:

1. Excellent Group – based on presentation and content (deep learning)

2. Good Group – based on content

3. Poor Group – based on content and presentation not done well (surface learning)

It should be reiterated that this approach is to develop a baseline for further investigation, to develop an understanding of how the student approaches problems and define improvements in the instructor's scholarship of teaching. In all, the assignment groupings are subjective and not numerically based so the researcher and instructor to provide insight as well, a benchmarking agent relative to the results of the grouping.

IV. Results

As reported earlier, the class consisted of 23 students (3 female and 20 male) mostly in their sophomore year within the Division of Construction Engineering and Management. Only 21 assignments were posted on Blackboard and only 19 could be de-identified and used for the analysis. The analysis of the assignments resulted in identifying: 3 Excellent, 12 Good and 4 Poor. It should be noted each sample is merely that, a sample of each group but none of them should be considered an absolute for the group.

The results offer the baseline insight that was sought relative to the student critical thinking related to the case study pedagogy. Baseline insights are as follows:

1. Imagination or lack of imagination was evident (case-effect)

2. The author indicated in his summary of the case study at the start of class that a 2 week blowout was required but not everyone identified this in their submission (attention to detail)

3. Support for the conclusions and how the student arrived at the conclusion was not identified by most students (support/citation)

4. Students seemed to gravitate to the following themes: safety, commitment to quality, schedule but they don't expressively illustrate a deep understanding of each (surface vs. deep understanding)

The following excerpts highlight some of our findings and relate them to how one of the three groups responded:

1. Excellent and related to item 2 & 3 (004 Student)

"This is a major issue because the project is aspiring to be a LEED certified project. To do this, all the fans must be turned on two weeks prior to commissioning to prep the building. This leaves only two weeks for LEED commissioning and final punch list items"

2. Excellent and related to item 1 (004 Student)

"In order to mend the other problems I noticed, I recommend bringing in more manpower. It was nice to see 75 men on site, however this is only approximately one man per thousand square feet. I think 100 men could be placed on the job without disrupting one another's work."

3. Excellent and related to item 1 & 4 (010 Student)

"…will help to reduce the temperature and humidity of the building resulting in faster drying of moist compounds but it will also improve the interior work environment for the workers and likely increase productivity."

4. Excellent and related to item 1 & 4 (015 Student)

"Delay your millwork which can be completed after the substantially completed date. Move these people to get the floors done. You can have school without cabinets, but not floors. Cabinets and such can be completed before school after August 20, and if need be on school weekends."

5. Good and related to item 4 above (001 Student)

"…raises safety concerns for the crews working inside without windows open in the mid-July weather. As well, the weather and lack of power worries me that the finishes being installed or already installed will not uphold their intended quality due to the hot/poorly ventilated environment."

6. Good and related to item 1 & 4 above (019 Student) – provide product data specification to substantiate your claim

"The adhesive to install the laminate floors was applied and left standing for three days, it is most likely dry and will require removal and replacement which will take unnecessary man power and time."

7. Good and related to item 1 & 4 above (014 Student) – provide product data specification to substantiate your claim

"The workers are most likely working at a slower pace since the conditions are not ideal. The nature of the work itself is also being affected as the drywall taping compound is taking longer to dry. Also, the mastic and tiling should typically be installed when the temperature is between 40-90 degrees F."

8. Poor and related to item 1 (006 Student) – no provision provided to indicate how to resolve

"I would personally tell the contractor and remind him about when the completion date is, and also remind him about any liquidated damages that might occur if the job is not completed in time."

9. Poor and related to item 1 & 3 (012 Student) – no calculation on number of workers need or not substantiation of why not safe

"…might both technical and safety issues with 75 people working on site."

V. Discussion

The research presented herein advances that which we have found relative to case study methods of course content delivery. It had long been confirmed that students enjoyed the experience, felt the learning was more active and engaging [2]. The next step in the process was taken by Yadav and explored "how cases can be used to improve students' conceptual understanding are equally effective at improving their problem-solving skills…" [4]. The need to explore other disciplines has been identified; therefore, CEM is poised to take on that challenge. The approach with the construction engineering student has taken a look at how the student is thinking and how

we can improve upon those skills. The end result could be the creation of a template that would assist faculty in following this path in presenting material in a case study pedagogy. Many items of interests will be discussed below illustrating the growth from this research based on building upon the previous literature. There are several limitations to this study and each has its own magnitude of importance. A summary of each is provided below:

1. Lack of direction – The class was not provided a rubric for the assignment so there was no consistency with the student responses. This freeform is a good approach in simulating industry conditions but when our goal is to mentor the student, especially at the sophomore level, then we must re-evaluate. The scaffolding we must do to get them to the point that they can succeed on their own in the free form culture must be considered. It may be that the semester must start out with a rubric and gradually remove the rubric by the end of the summer. Another approach would be to utilize rubrics at the sophomore level but remove them during the senior level courses.

2. Student control group – The analysis doesn't compare students against other students as described via Yadav's 2014 paper [4]. The concern with this is that if we create a cohort that does not get exposed to the case study methodology in learning specific content then we may inadvertently discriminate a subset of students from a learning opportunity that is authentic and rich in comparison to their traditional experience.

3. Population – The population studied is small because of the current enrollment figures for CEM. The lack of numbers may or may not result in a lack of diversity which is something that should be considered in future research.

4. Analysis bias – It is easy for the researcher to review the assignments and be biased in classification based on presentation and not merely reviewing the content of the student thought process.

None of the limitations are substantial nor egregious enough to rule the analysis void. They do serve as notice for future research points of emphasis to address so validity of the research is increased related to the case study pedagogy. There is much to take away from this research in the form of classroom practices and further research:

1. Design of Instruction – The result will help us review how the students think and how we can help them via the approach taken in the classroom. The instructor will focus on cognitive apprenticeship by working through a similar type problem using cause-effect diagrams and supporting decision with facts. The format of the case study and the lesson plan for the scaffolding in class can be constructed and shared with fellow faculty to assist them in improving their delivery methods. The entire exercise will benefit the researcher (instructor of CEM 28000). Items to integrate:

a. Industry exposure is good but make sure it remains relevant and youthful so students can relate.

b. Explicit instruction is a must and hopefully the student will not only have a deeper sense of learning but the student will understand the importance of explicit instructions with regard to their future managerial style.

c. A scholarly innovation to ponder is the inclusion of this paper as part of the reading literature for future sections of the CEM 28000 course. If the students are made aware of the importance of the case study method, then it will resonate in how they approach problems. It is not much different than the thought process associated with the instructor taking a cognitive apprentice method in working through a problem with the students so they understand the presentation style, cause-effect process and general discussion on how to assert and support claims.

2. Research – The categories of research seem endless once this specific research effort is finalized. Thoughts include: a. Diversity – Do certain subsets of students (engineering discipline, gender, nationality) benefit more from case based instruction than others?

b. Growth – Can we follow a cohort of students from their sophomore year through senior year to ascertain the potential intellectual and professional growth realized by the student by using case based instruction? If it is found that the students do grow intellectually as a result and become better problem solvers then we will have solved a problem that industry has indicated is a problem – students graduating with nothing more than a technical appreciation of their discipline but unable to navigate their profession in an efficient inter-disciplinary nature [2].

c. Recruiting – Can we evaluate the effect that this pedagogical method would have on retention of CEM students or engineering students as a whole?

VI. Conclusion

The preparation of the construction engineering student is achieved by student centered active learning by focusing on the case study and apprenticeship pedagogical methods. This will allow us to link technical content with applied knowledge and experiences [2]. Further investigation as discussed in the "Discussion and Implications" section will be able to address if we can train students to develop skill sets. The conclusion is that students either have a grasp or don't have a grasp on: how to develop a basis of argument and evaluate impact. The basis of argument is the ability to evaluate the risk/reward and defend the decision or action to be taken. In the assignments collected, some students could identify cause-effect; therefore, they could respond appropriately. This is where we want all the students to be with their cognition – the ability to evaluate the cause-effect of a particular scenario. The next step after that will be to mentor the student in developing techniques to support their claims by using anecdotes, applicable codes and/or technical manuals. Additionally, we want the student to explore the impact of their decision making process: external, internal, financial and/or schedule. This is merely a sampling of criteria that the students should be aware. Their knowledge base of the various criteria will grow with experience yet be a direct reflection of the unique project they are working on.

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